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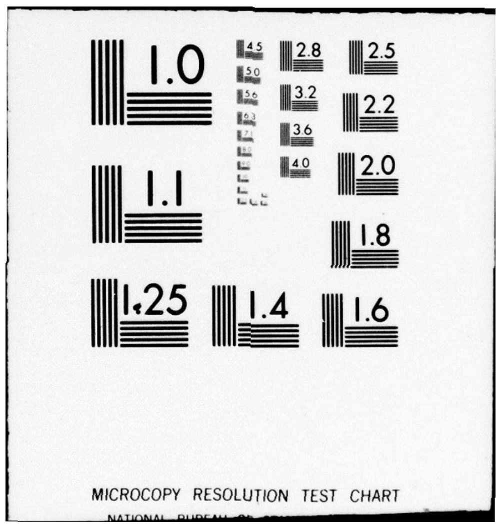
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CETA 79-5

Estimating Nearshore Significant Wave Height for Irregular Waves

by
William N. Seelig

COASTAL ENGINEERING TECHNICAL AID NO. 79-5
OCTOBER 1979

U.S. ARMY, CORPS OF ENGINEERS
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Design curves for predicting nearshore significant wave height for irregular wave conditions, given deepwater wave conditions and the nearshore bottom slope, are presented. Examples of the curves used are given. The design curves were developed using the analytical model of Goda (1975).

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PREFACE

This report presents procedures developed by Goda (1975) for estimating nearshore significant wave heights for irregular wave conditions, using known offshore (deepwater) wave conditions and the nearshore bottom slope. Goda's methods represent an important increase in the engineering community's ability to predict waves propagating into shallow water. The method is based on a number of simplifications and empirical adjustments but appears to represent laboratory and limited field data reasonably well. It is suggested that the method be used; however, the results should be carefully evaluated to confirm that the method is not used outside of its range of applicability.

Procedures for predicting design wave conditions for irregular waves are not discussed in the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977). The selection of design waves in the SPM (Section 7.12) is based on monochromatic wave theories. This work was carried out under the offshore breakwaters for shore stabilization program of the U.S. Army Coastal Engineering Research Center (CERC).

This report was prepared by William N. Seelig, Hydraulic Engineer, under the general supervision of Dr. R.M. Sorensen, Chief, Coastal Structures Branch.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 1966, 79th Congress, approved 31 July 1945, as supplemented by Public Law 1972, 88th Congress, approved 7 November 1963.

Ted E. Bishop

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

FIGURES

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SYMBOLS AND DEFINITIONS

d	stillwater level or water depth that would be found if the waves were not present
g	acceleration due to gravity
H_b	nearshore breaker height predicted by monochromatic wave theory
H'_o	unrefracted deepwater significant wave height (this is the equivalent wave height that would occur with refraction accounted for at the point of interest)
H_s	nearshore significant wave height
L_o	deepwater wavelength
m	the average beach slope approximately one-half to one wavelength seaward of the point of interest
S_w	wave setup or increase in effective water level that occurs due to radiation stress (S_w can be negative; when S_w is negative it is referred to as setdown)
T	wave period (for irregular waves use the period of peak energy density)

ESTIMATING NEARSHORE SIGNIFICANT WAVE HEIGHT FOR IRREGULAR WAVES

by
William N. Seelig

I. INTRODUCTION

The selection of design waves, as discussed in Section 7.12 of the Shore Protection Manual (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977)[1], is based on monochromatic wave theories. The monochromatic wave theory assumption that waves have a constant height and period is best applied to swell (i.e., waves generated far from the point of interest). However, wind waves and waves generated by nearby storms are often irregular (i.e., height and period vary from one wave to the next), as evidenced by numerous wave records taken along the coasts of the world (see Fig. 1 for two examples). This report presents design curves for the prediction of nearshore significant wave height that include effects of wave irregularity, based on the procedures developed by Goda (1975)[2], using known offshore (deepwater) wave conditions and the nearshore bottom slope. This report does not address factors such as refraction, diffraction or nonbreaking forms of wave energy loss. A method of accounting for wave refraction for irregular waves is discussed in Seelig and Ahrens (in preparation, 1979)[3].

The analytical model requires the following assumptions: (a) the deepwater unrefracted significant wave height, H_o', and period, T, are known; (b) the bottom depth is continuously decreasing from deepwater shoreward; (c) the deepwater wave heights have a Rayleigh distribution; (d) surf beat, wave setup, and breaking limits can be described by empirical formulas; (e) shoaling is nonlinear; and (f) broken waves re-form at lower heights. Larger waves are assumed to break in deeper water and re-form, so that nearshore waves have a non-Rayleigh distribution. The significant wave height nearshore cannot be used to predict other nearshore height parameters, such as the mean height, because the height distribution is non-Rayleigh.

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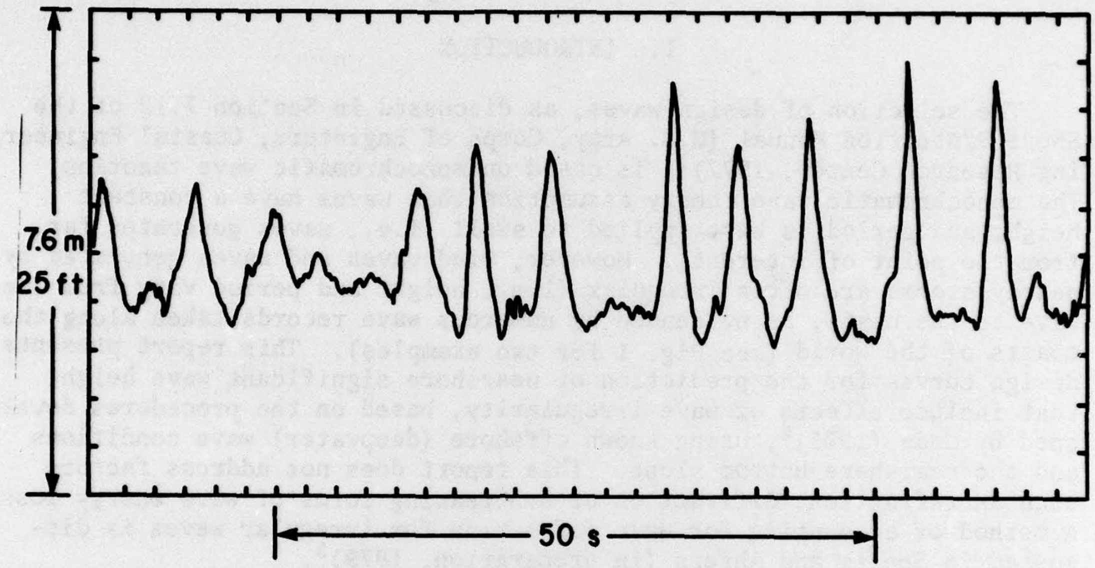
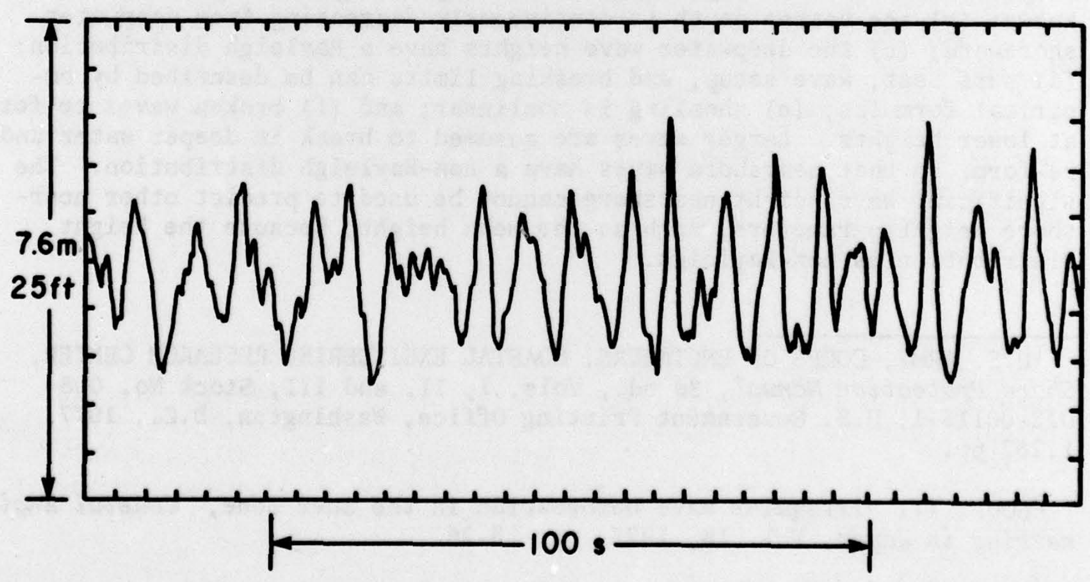
[1]U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, 3d ed., Vols, I, II, and III, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977, 1,262 pp.

[2]GODA, Y., "Irregular Wave Deformation in the Surf Zone," *Coastal Engineering in Japan*, Vol. 18, 1975, pp. 13-26.

[3]SEELIG, W., and AHRENS, J., "Estimating Nearshore Conditions for Irregular Waves," U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., (in preparation, 1979).



Nags Head, N.C., 1840, 20 Sept. 1972



Huntington Beach, Calif. 1800, 13 Mar. 1973

Figure 1. Selected nearshore wave records.

Figure 2 illustrates some conditions assumed to occur nearshore. The local significant wave height (H_s defined as the average height of the highest one-third waves) is one of the most important parameters to designers. For design curves that give the maximum, mean, or root-mean-square wave height or wave setup, see Seelig and Ahrens (in preparation, 1979)[4].

II. METHODS FOR USING THE DESIGN CURVES

The design curves (Figs. 3 to 6) are plots of local significant wave height divided by the stillwater depth, H_s/d, versus the ratio of d/gT^2. Curves are given for various deepwater wave steepness, H_o'/gT^2. The bottom slope, m, is the average slope one-half to one wavelength seaward of the point of interest. The location of the transition between wave setup and setdown is shown on each curve (where S_w changes from positive to negative). The ratio H_s/d may be large because the effective water depth may be greater than the stillwater depth due to wave setup. Where setup is positive the effective water depth is greater than the stillwater depth. The method of presenting the data was selected because nearshore wave height can be predicted from deepwater wave conditions (method 1, described below) or alternatively, waves measured in finite depth water can be used to estimate wave height at other shallower depths (method 2, described below). For values that fall between the curves use linear interpolation; for bottom slopes flatter than 1 on 100 use Figure 3. In some cases more detailed calculations or examination of wave height distribution may be necessary. If so, the computer program GODAS (720X1R1CB0) may be used to predict wave height distributions. This program may be obtained from the Coastal Engineering Research Center, Automatic Data Processing Coordinator, Kingman Building, Fort Belvoir, Virginia 22060.

The computer program assumes that deepwater wave heights have a Rayleigh distribution. If in a design situation the deepwater waves are known to be non-Rayleigh, which may occur with multipeaked spectra, the deepwater height distribution in the computer program can be changed to the assumed distribution function and the program used directly to make predictions.

The analytical model assumes that the water depth is continuously decreasing from deepwater shoreward, and it is not shown what effects offshore bars have on nearshore wave height. As a first approximation for coasts with offshore bars, the wave height shoreward of the bar should be taken as equal to the predicted height at the bar crest location (Y. Goda, Port and Harbour Research Facilities, Tokyo, Japan, personal communication, 1978). At locations shoreward of the bar where the water depth is less than the depth at the bar crest, the methodology can be used to predict wave heights.

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[4]SEELIG, W., and AHRENS, J., op. cit., p. 7.

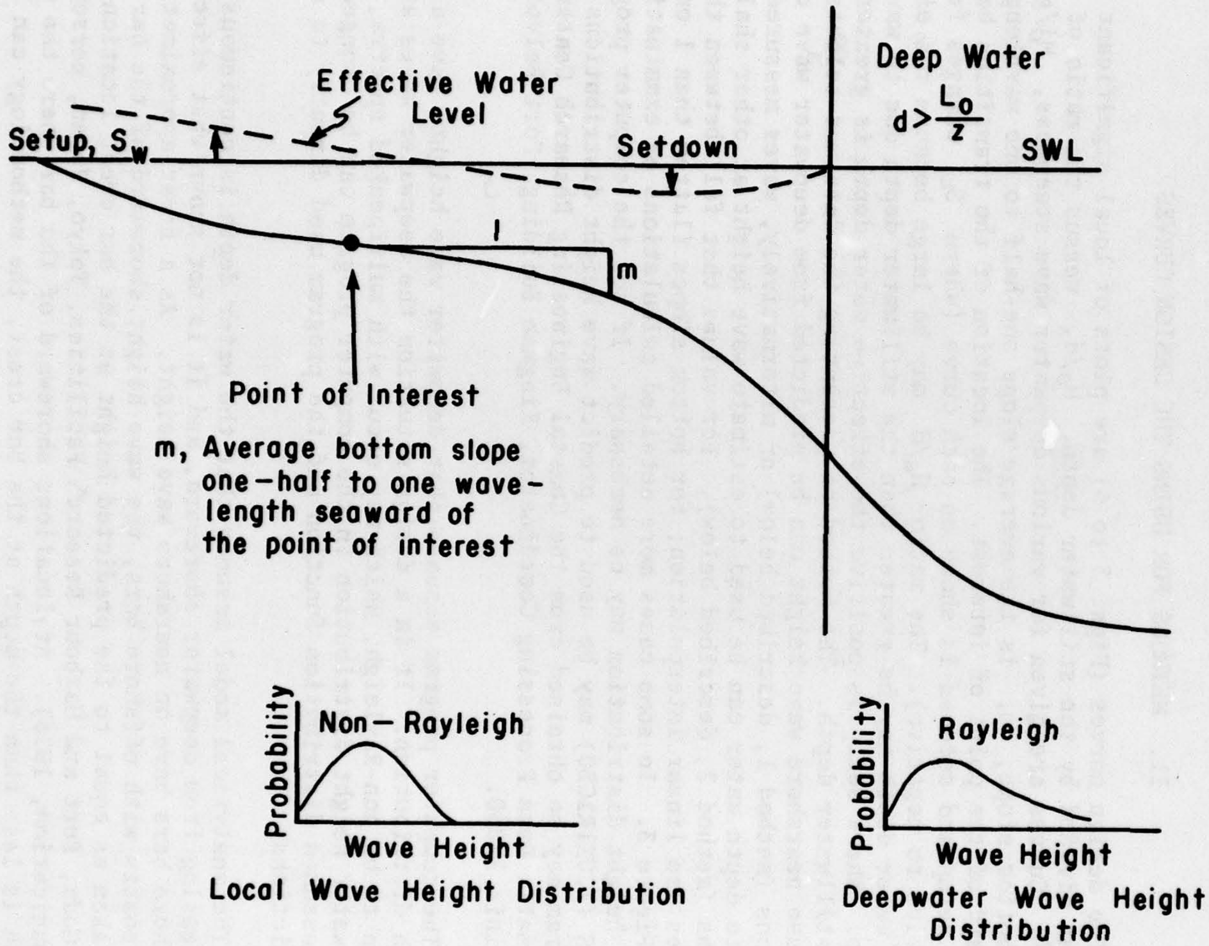

Figure 2. Conditions in the nearshore zone.

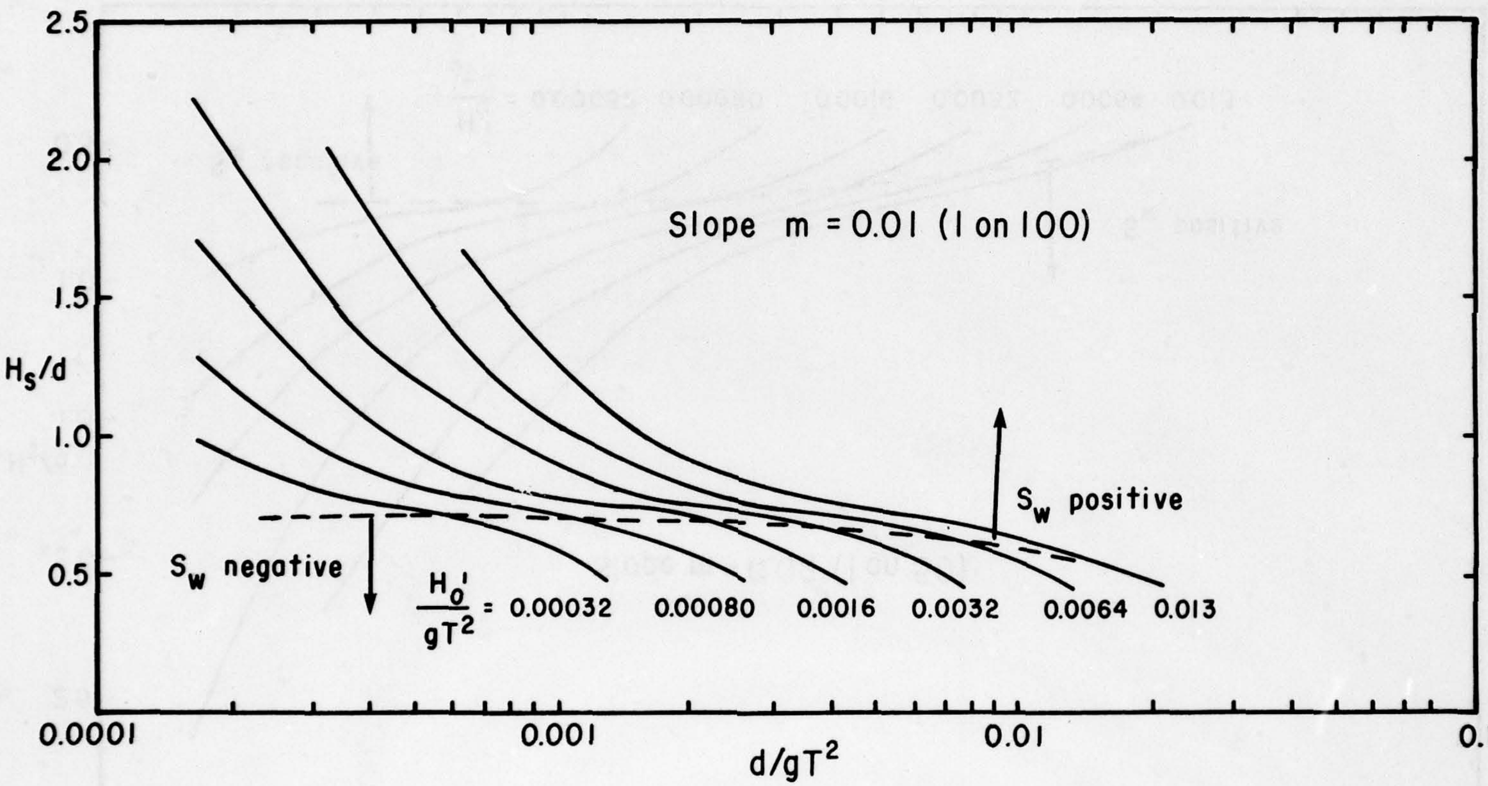

Figure 3. Nearshore significant wave height diagram for a bottom slope of 1 on 100.

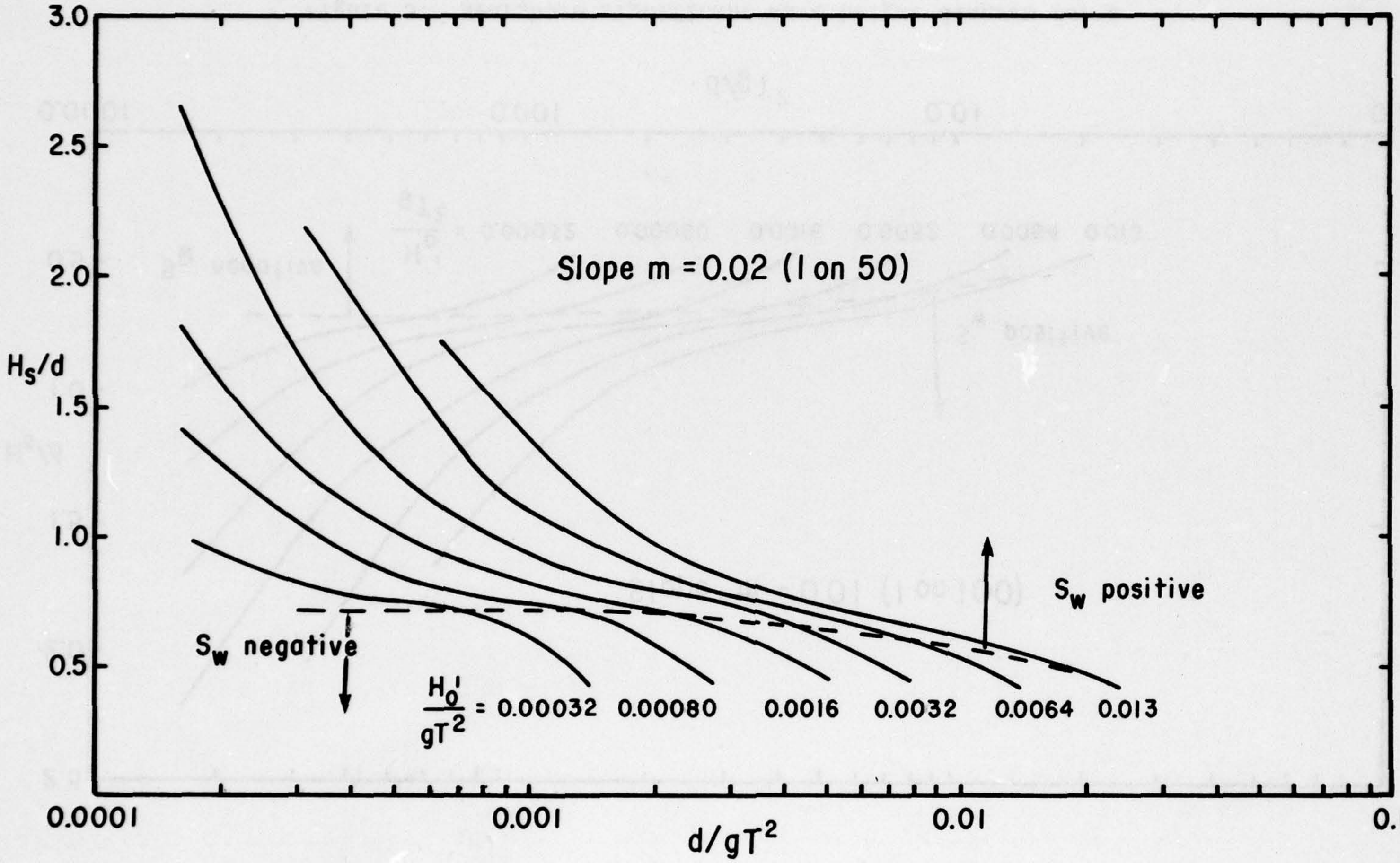

Figure 4. Nearshore significant wave height diagram for a bottom slope of 1 on 50.

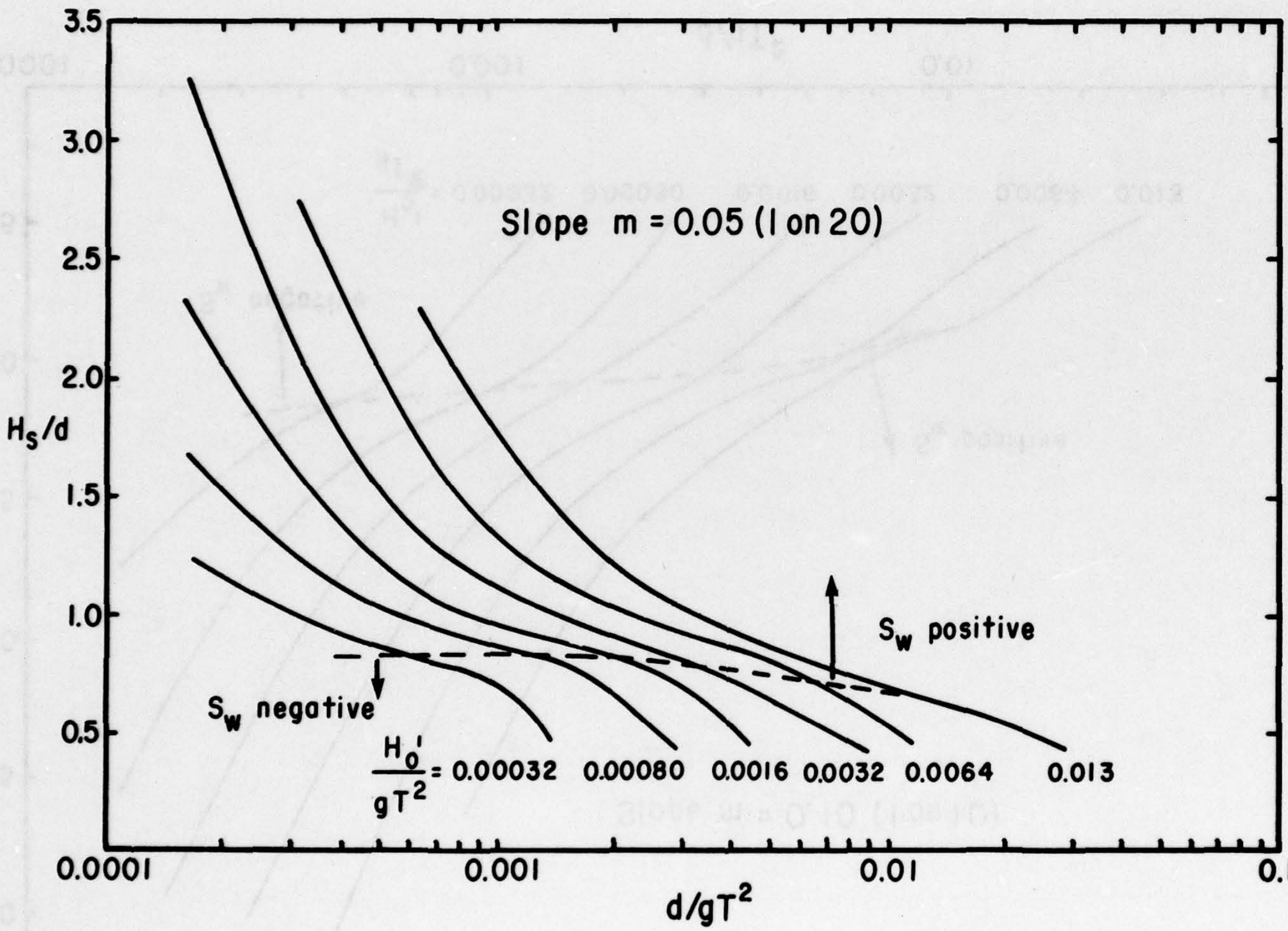

Figure 5. Nearshore significant wave height diagram for a bottom slope of 1 on 20.

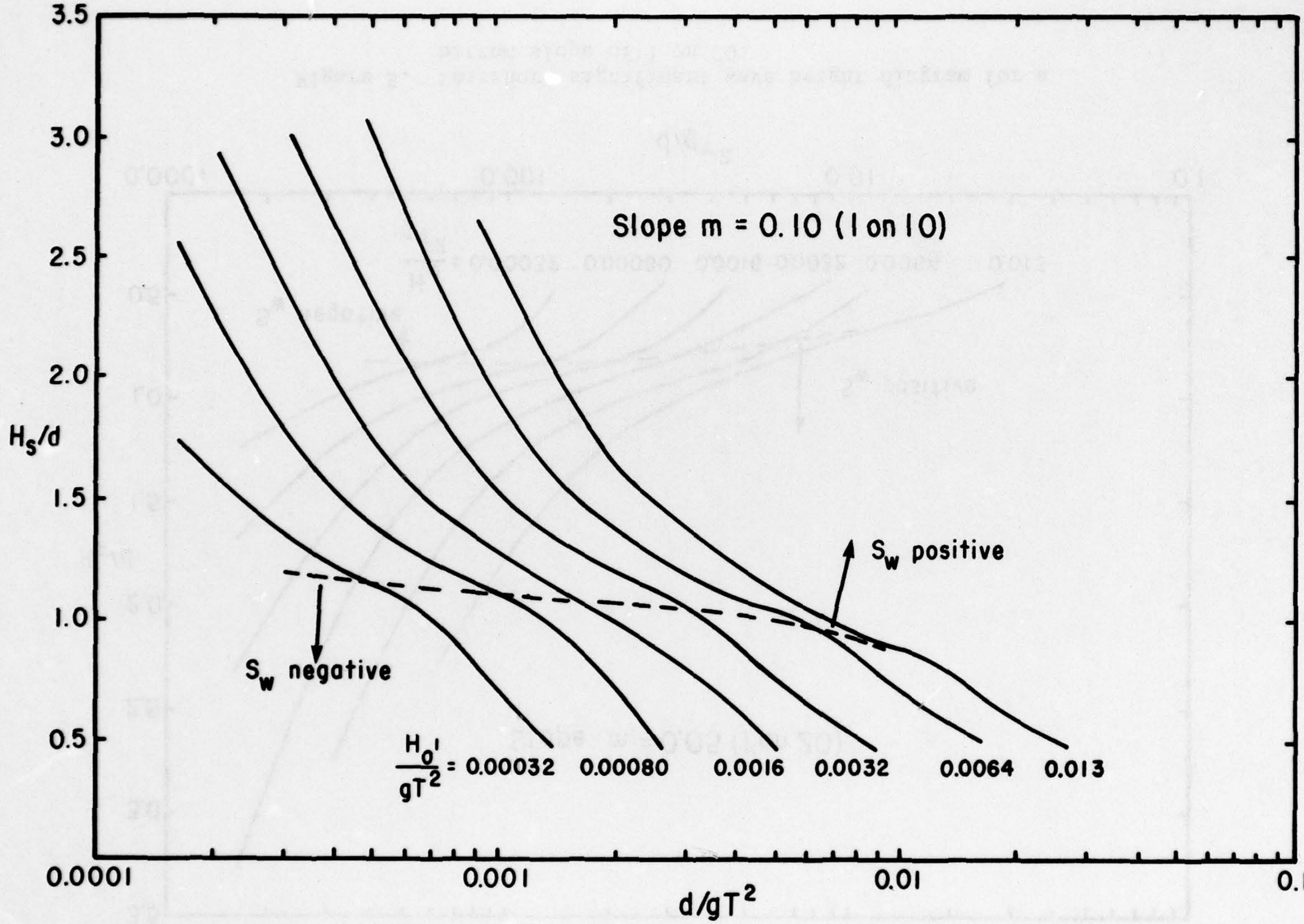

Figure 6. Nearshore significant wave height diagram for a bottom slope of 1 on 10.

Method 1

If the deepwater wave conditions, H_o' and T, and bottom slope, m, are known, use the following procedure for predicting nearshore significant wave height:

a. Determine the ratios, H_o'/gT^2 and d/gT^2, where d is the stillwater depth at the point of interest.

b. Enter the appropriate graph corresponding to the bottom slope, m, with the value of d/gT^2 on the ordinate. Find the point where d/gT^2 and H_o'/gT^2 intersect and read the value of (H_s/d) off the abscissa.

c. Finally, $H_s = d(H_s/d)$.

Method 2

If local conditions at one location are known $\left((H_s)_1, d_1, m, T\right)$ the significant wave height, $(H_s)_2$, at another shallower depth, d_2, can be determined:

a. Compute $(H_s)_1/d_1$ and d_1/gT^2, enter these values on the abscissa, ordinate, and determine where they intersect.

b. Determine the H_o'/gT^2 where the values intersect. H_o' can be found directly; $(H_s/d)_2$ and $(H_s)_2$ can be found as illustrated in method 1.

III. EXAMPLES OF USE

* * * * * * * * * * * * * * * * EXAMPLE 1 * * * * * * * * * * * * * * * * *

GIVEN: The conditions $m = 0.02$ (1 on 50 slope), $T = 9$ seconds, and $H_o' = 8.2$ feet (2.5 meters).

FIND: The significant wave height where $d = 6.56$ feet (2.0 meters).

SOLUTION: Using method 1,

$$H_o'/gT^2 = \frac{8.2}{32.2(9)^2} = 0.0031$$

and

$$d/gT^2 = \frac{6.56}{32.2(9)^2} = 0.0025 .$$

From Figure 4, $(H_s/d) = 0.75$;

therefore,

$$H_s = d\ (H_s/d) = 6.56(0.75) = 4.9 \text{ feet (1.5 meters)} .$$

This nearshore predicted significant wave height is lower than if waves were monochromatic. If the SPM monochromatic design breaker height curves (Fig. 7-4 in the SPM) were used with this example, the predicted breakwater height, H_b, would be:

$$H_b = 6.23 \text{ feet (1.9 meters)} .$$

* * * * * * * * * * * * * * * * * * EXAMPLE 2 * * * * * * * * * * * * * * * * * *

GIVEN: Wave conditions were measured as T = 16 seconds and $(H_s)_1 = 6.56$ feet (2.0 meters) where the bottom slope was m = 0.05 (1 on 20) and water depth was $d_1 = 13.1$ feet (4.0 meters).

FIND: The significant wave height at a second location where $d_2 = 3.28$ feet (1.0 meter).

SOLUTION: Using method 2,

(a) $$(H_s)_1/d_1 = \frac{6.56}{13.1} = 0.5$$

and

$$d_1/gT^2 = \frac{13.1}{32.2(16)^2} = 0.0016 .$$

(b) The abscissa and ordinate values in (a) intersect where

$$H_0'/gT^2 = 0.00048 \text{ on Figure 5}$$

(c) At location (b), $d_2/gT^2 = \frac{3.28}{32.2(16)^2} = 0.0004$

(d) At $d_2/gT^2 = 0.0004$ and $H_0'/gT^2 = 0.00048$, $(H_s/d)_2 = 0.83$

(e) Finally, the predicted significant wave height at location (b) is $(H_s)_2 = d_2 \; (H_s/d)_2 = 3.28(0.83) = 2.7$ feet (0.83 meter) .

* *

IV. SUMMARY

Curves for estimating nearshore significant wave heights for irregular waves using the analytical model of Goda (1975) are presented with examples for use. The standard use of the SPM would result in monochromatic nearshore breaker heights which are larger than the irregular wave significant heights given in this report.

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